"CORRESPONDENCE TRACKING"

Global Change file

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** PENULTIMATE DRAFT **

April 23, 1992

MEMORANDUM FOR DR. ALLAN BROMLEY

FROM: Jonathan Wiener
Policy Counsel

SUBJECT: **Review of Cost Estimates of Limiting Greenhouse Gas Emissions**

You requested a summary and review of the estimates of the cost to limit net greenhouse gas emissions. As you pointed out, several studies with different assumptions and different methodologies have attempted to answer this question. This memorandum summarizes very briefly a few highlights for your information.

Summary

Economic models of "stabilizing" US emissions of fossil fuel CO2 (by holding them at or below 1990 levels by 2000 and thereafter) estimate the cost of such a policy to be a 0.1-0.6% loss of US GDP from baseline forecasted GDP in 2000. (One model (DRI) shows higher costs, around 1-2% in 2000.) Costs are estimated by these models to rise faster than GDP growth as stabilization is maintained, to 0.3-1.5% of GDP by 2020, and 0.4-2.1% of GDP by 2050. Cutting CO2 emissions further, such as a 20% reduction below 1990 levels by 2010-2020, would raise costs to 1.0-3.8% of GDP in 2020. Cutting CO2 sooner raises costs on an absolute basis, even without discounting future costs.

Engineering studies show smaller costs, but are based on questionable assumptions about discount rates and market penetration of selected technologies.

Efficient mechanisms the US has advocated can make a significant difference in costs at any level of control. Allowing international flexibility to control emissions where the costs of control are lowest (e.g. through emissions trading) could achieve the same emissions goal while lowering costs about 20-50%. Allowing flexibility under a "comprehensive approach" for each country to devise its best mix of the most cost-effective measures to control GHG emissions or expand GHG sinks could cut costs by up to 90% in the US (where some CH4 methane options, tree planting and CFC reductions are cheaper, per GWP avoided, than restricting fossil fuel CO2), and 85% in India (where restricting CO2 is cheaper than restricting CH4).

To give some comparative perspective to the estimated cost of stabilizing US CO2 emissions by 1990 levels by 2000 (ranging from 0.1-2.0% of GDP foregone by 2000, depending on the model):

- Today the US spends about 2% of GDP on all environmental protection, which is projected to rise to 3% by 2000. The Clean Air Act Amendments of 1990 are expected to cost around $20 billion per year, or 0.4% of GDP.

- Nordhaus estimates the benefits to the US of preventing an assumed 3 degree C rise in global surface mean temperature at around 0.26% of GDP through 2050 (not accounting for low-probability, high-impact discontinuous damages from climate change).

- Stabilizing global forests (preventing further deforestation) would achieve as much or more reduction in global CO2 emissions as stabilizing OECD emissions of CO2 at 1990 levels by 2000, but at less than 1/10 the global cost, and with additional side benefits in biodiversity conservation.

I. Costs of limiting energy sector CO2 emissions

Several economic models have been employed to estimate the cost of limiting GHG emissions. These studies assume that emissions will grow between now and 2000 absent imposition of a restriction on emissions such as a tax. They do not explicitly assume the effects of policy actions such as those in the US "Action Agenda" to limit net emissions, but in general they do assume the overall effects of the Clean Air Act and other already-adopted programs listed in the Action Agenda.

Results vary from different studies using different economic models, because different models incorporate different economic structures and dynamics, such as the availability of new technology; and because different studies start with different assumptions about future economic growth, fuel prices, and so-called "autonomous" energy efficiency improvement (AEEI).

Cost estimates are typically reported in terms of a reduction in baseline (no policy action) forecasts of GNP. GNP is an imperfect measure of overall well-being; for example, expenditures on equipment installed to restrict emissions raise the calculated level of GNP. Meanwhile the baseline (no action) GNP forecasts from which costs are subtracted do not appear to account for the reduction in economic well-being (if any) that unrestricted

emissions might impose.

A. OECD and EMF model comparisons

The most oft-quoted proposal for a "target" is to hold CO2 emissions from the energy sector to 1990 levels in the year 2000, "stabilizing" them by holding emissions to no more than that level permanently after 2000.

The OECD recently compared several models for their estimates of the economic cost to stabilize world CO2 emissions through uniform action by every country to stabilize its own emissions at 1990 levels by 2000:

Model	% GDP Loss if World Fossil Fuel CO2 Emissions are Held to 1990 Levels after 2000			
	2000	2020	2050	2100
Stabilize CO2 emissions by every country at 1990 levels by 2000:				
Manne-Richels				
US	0.6	1.0	2.1	2.4
Other OECD	0.4	0.8	1.3	1.6
China	1.6	2.6	4.0	5.2
World	1.1	2.2	2.8	3.5
Edmonds-Reilly				
US	0.2	0.6	0.8	0.4
Other OECD	0.3	0.7	0.9	0.9
China	1.2	3.4	5.6	12.7
World	0.2	1.0	1.7	2.6
GREEN (OECD)				
US	0.1	0.3	0.4	
Other OECD	0.2	0.3	0.6	
China	0.7	3.4	5.5	
World	0.4	1.7	2.5	

Source: regional estimates read from OECD, "Costs of Reducing CO2 Emissions: Evidence from Six Global Models," Restricted (13 March 1992), Chart 6 (with GREEN curve for "Other OECD" revised per facsimile from Andrew Dean, OECD, 17 April 1992). World estimates read from id., chart 8.

The models show that stabilization of world emissions via uniform actions by every country would cost the US between 0.1-0.6% of GDP in 2000, rising to 0.4-2.1% in 2050.

The Stanford Energy Modeling Forum (EMF 1992) performed a similar model comparison with 8 models (including the three shown above) and found that stabilizing US emissions at 1990 levels after 2000 would impose a cost of 0.5-1.5% of GDP in 2020. This range is somewhat higher than the range of 0.3-1.0% in the OECD model comparison. EMF also found that achieving a 20% reduction from 1990 levels by 2010 would cost 1.0-2.5% of GDP in 2020. (EMF 12, "Executive Summary" draft 2/12/92, p. ii & Exhibit 1.)

In each model comparison, the models are standardized to reflect common assumptions about baseline economic growth, population growth, and fuel price projections. In the EMF comparison exercise, technology assumptions were also standardized. In the OECD comparison, the differences in costs across models mainly reflect differences in:

- baseline emissions growth assumed (in billion tons of carbon):

Model	Baseline worldwide CO_2 emissions 1990	2020	2050
Manne-Richels	6.003	9.520	14.992
Edmonds-Reilly	5.767	8.180	11.838
GREEN	5.815	10.806	18.998

- AEEI: 1% per year in Edmonds-Reilly and GREEN; 0.5% per year in Manne-Richels.
- availability of "backstop" lower-emitting or non-emitting technologies.

B. Studies using DRI model.

(1) DRI-McGraw Hill (Jan. 1992) examined the cost of stabilizing OECD emissions of CO2 at 1988 levels in 2000, and then reducing them 10% below the 1988 level by 2010 and 20% below the 1988 level by 2020. It found:

	Average % GNP lost during decade ending 2000	2010	2020
US	0.3	3.5	3.8
Europe	0.7	2.0	2.9
Japan	0.6	1.5	1.8
Australia	1.2	3.4	4.1
All OECD	0.5	2.5	3.0

Source: DRI, "Economic Effects of Using Carbon Taxes to Reduce Carbon Dioxide Emissions in Major OECD Countries" (Jan. 1992).

(2) The US <u>Congressional Budget Office (CBO)</u> (August 1990) studied the impact on the US economy of unilaterally imposing a $100 per ton of carbon tax on fossil fuels, phased in from $10 per ton of carbon in 1991 and rising to $100 per ton by 2000. CBO used three models to assess this tax: the DRI model, the Jorgenson DGEM model, and the PCAEO model from DOE. Assuming that only the US imposed this tax, CBO found:

	% GNP foregone by year				% change in 2000 CO2 emissions level compared with 1988 levels
	1993	1995	1997	2000	
DRI	1	2	2	2	- 6
DGEM				1	-27
PCAEO					+ 5

Source: CBO, "Carbon Charges as a Response to Global Warming: the Effects of Taxing Fossil Fuels" (Aug. 1990), Tables 3. 5 and 6. Missing data not reported by CBO.

The variety of emissions results reflects differences in the models. The DGEM is a general-equilibrium model in which new technologies are employed as soon as they become economically competitive; it abstracts from transition times and costs and is therefore better suited to long-run equilibrium analysis than to predicting real changes in emissions and GNP over time. CBO also noted that imposing the tax suddenly, instead of phasing it in over ten years, could raise the cost to 5% of GNP.

Using the Edmonds-Reilly model to look out to the year 2100, CBO found that this unilateral $100 tax would impose a cost of around or just over 1% of GNP below forecast baseline growth. (<u>Id.</u>, Fig. 8.) The unilateral US tax would keep US emissions growing only slightly above 1988 levels through 2050, and then reduce them thereafter, roughly approximating "stabilization" in the Edmonds-Reilly model run. (<u>Id.</u>, Fig. 7.)

If the tax were also imposed multilaterally by other OECD countries, the US loss of GNP would still be about 1% in the Edmonds-Reilly model run (<u>id.</u>, Figure 8). But CBO found the emissions impact would differ significantly between a unilateral US tax and a multilateral tax. The unilateral US action would reduce global emissions insignificantly and delay a doubling of global CO2 concentrations by only 3 years. A multilateral $100 tax would reduce global emissions about 25% from baseline growth (allowing US emissions to grow after 2050 while restraining others' emissions more), and delay doubling of global CO2 concentrations by 17 years. (<u>Id.</u>, Figs. 7, 9, 11.) (Note that applying the same tax across all

OECD countries, instead of requiring the same emissions target to be met by all countries, allows each country's emissions level to vary according to its marginal cost of control. Allowing emissions trading would offer similar flexibility.)

B. Effect on world emissions of action by OECD alone.

OECD found that an OECD-only stabilization policy would reduce global CO2 emissions by only 11% from baseline growth by 2050. (OECD, "Costs of Reducing CO2 Emissions: Main Issues for Discussion," Restricted (27 March 1992), par. 15.) This is similar to the finding by the CEA task force in 1990 that stabilizing OECD emissions of CO2 in 2000 would only reduce global CO2 emissions in 2025 by about 10%. (US Interagency Task Force, "Economics of Long-Term Climate Change: A Preliminary Assessment," DOE Sept. 1990, Table III.2.)

These figures are based on arithmetic changes from projected emissions; they abstract from world trade interactions between regions that would ensue from restrictions in one region such as OECD. In particular, OECD-only restrictions on emissions could reduce fossil fuel consumption in those countries and thus lower the world price of fossil fuels, leading to increased consumption elsewhere. DOE (Sept. 1991, chapter 10) reports a run with the Edmonds-Reilly model showing that this effect offsets about 20% of the initial emissions reduction achieved within the OECD. Over the longer term, the locus of production of carbon-intensive goods could shift out of the OECD countries. Stanford EMF reports that this effect could be "significant," making the impact on global emissions "drop off sharply." (EMF 12, "Exec. Summary," draft 2/12/92, p. v.) Hence the estimate that OECD stabilization would reduce global emissions by 10-11% must be taken as an upper bound.

D. Transition costs

Few of the economic models give a good picture of the actual costs that would be felt in the transition period. CBO (1990) noted that if a $100 tax were imposed immediately instead of phased in over ten years, the 1-2% GNP cost could rise to 5%. This finding is supported by the work of the Stanford Energy Modeling Forum (EMF 1992), which found that a phased-in tax would achieve the same cumulative emissions outcome by the middle of the next century as a 20% reduction from 1990 emissions levels by 2010, but at a 30-40% cost savings. (EMF 12, "Executive Summary" draft 2/12/92, p. iii.) Put another way, the sooner or the deeper the control policy, the higher the cost; and costs rise more than linearly with the depth or onset of the control. In part this

reflects model assumptions about the availability of non-carbon technologies over time; as they become more available, the cost of a carbon tax declines. Delaying a control policy can thus significantly reduce its cost, even for similar effects on net emissions.

CBO (1990) also examined the transitional impact of the phased-in tax on different industries, using the DGEM model. It found large sales losses in coal, oil and natural gas production (70%, 30% and 20% reductions, respectively); chemicals; transportation; printing & publishing; rubber & plastics; and machinery.

Steger (1992) used the DRI model and scenario (see 1(C) above) to project regional employment impacts within the US. He took industry-by-industry effects of a carbon tax and allocated job losses regionally according to the share of that industry's jobs in each region. He found the most severe impacts by number of jobs lost in PA, KY, LA, TX, CA, and IL; and the most severe by percentage of jobs lost in KY, WV, AL, MS, LA, TX, OK, NM, KS, UT, WY, MT, and ND.

Steger's analysis is limited by the DRI model's representation of employment effects (showing oscillating effects in early years, then a rise in unemployment, and then a curious fall in unemployment below baseline). It is also limited by its arithmetic method of allocating projected industry job losses to states without any sensitivity to regional variations within industries (e.g. variations in the age of capital, energy mix, supply mix, competitiveness of product market). These intra-industry variations may be significant for regional job losses.

E. Eliminating energy subsidies

OECD analysis using the GREEN model found that eliminating existing energy subsidies in all countries (over the period 1990-2000) would reduce global CO2 emissions 20% below baseline growth by 2050. All of this reduction in projected growth would occur in non-OECD countries. Real income under this scenario is projected to rise dramatically over baseline forecast in Eastern Europe and the CIS, by 9.2% in 2005 and 17.6% in 2050. OECD countries gain 0.3% real income over baseline by 2005 but lose 0.5% by 2050. World real income rises 0.2% in 2005 and 1.4% in 2050. (OECD, "Costs of Reducing CO2 Emissions: Main Issues for Discussion," Restricted (27 March 1992), par. 11 and table 2.)

Similar analysis at the World Bank indicates that eliminating energy subsidies in Eastern Europe, the CIS and developing countries would reduce global CO2 emissions in 1995 by 11% from baseline forecasts (World Development Report, forthcoming 1992, Table 8.1).

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II. Internationally efficient CO2 limits: capturing variations in the marginal cost of control through, e.g., emissions trading

Uniform limitations across countries, in which every country must meet the same emissions quantity target (e.g. "stabilization of national emissions"), are inefficient because the marginal cost of limiting emissions varies across countries. The cost estimates above assumed such uniform, identical action by all countries. Yet the variation of marginal costs across countries were significant; in OECD's comparisons, for example, marginal costs varied over a factor of 10 from the least-cost emissions avoider (China) to the highest-cost emissions avoider (OECD-Pacific).

OECD compared the costs of a uniform policy in which all countries must limit emissions by the same degree with a more efficient policy in which the most reductions are obtained where the marginal cost of abatement is lowest. Such an efficient mechanism could be designed by applying the same tax to all countries (rather than requiring the same emissions result in different countries), or by allowing trade in emissions allowances.

OECD used two models to compare the costs of uniform and allowance-trading policies to reduce OECD-country emissions by 2% per year under baseline forecast. In the GREEN model, employing an efficient policy to limit emissions cut the cost of achieving the goal by about 50% in 2020 and 27% in 2050. In the Edmonds-Reilly model, cost savings were 16% in 2020 and 11% in 2050. ("Evidence from Six Global Models," Table 5.)

III. Efficient Comprehensive Policies

A. Limiting all GHGs from the energy sector, not just CO2

The above studies concentrate on CO2 emissions. But emissions from the energy sector include other GHGs, such as CH4, CO, NOx, and VOCs. The marginal cost of reducing these other GHGs may be lower than that of reducing CO2. For example, recovering CH4 from coalbeds may be low cost because the CH4 can be resold as fuel.

DOE compared the cost of a CO2 tax on US energy producers with the cost of a GWP tax (covering all GHGs) on US energy producers. DOE found that to reduce US energy-sector CO2 emissions by 20% from 1990 levels by 2010, using a tax on the carbon content of fossil fuels, would require a tax of $539 per metric ton of carbon put in place after 1990 and would impose a total economic cost of $128 billion per year in 2010. To reduce US net GHG emissions from the energy sector by the same degree, using a GWP-weighted tax on fossil fuels, would require a tax of $180 per metric ton of carbon-

equivalent and would impose a total economic cost of only about $30 billion per year in 2010. See Richard A. Bradley, Edward C. Watts & Edward R. Williams, Limiting Net Greenhouse Gas Emissions in the United States, Volume II: Energy Responses at 8.10-8.12, (US Dept. of Energy, Office of Environmental Analysis, Sept. 1991). **Hence even when constrained to act only within the energy sector, broadening from CO2 to all GHGs reduces costs by about 75%.**

This comparison must be taken as illustrative, since it relies on GWP factors for the GHGs based on the 1990 IPCC Report, and includes low-cost CFC reductionss at their full direct GWP. The comparison would also differ in different countries.

B. Fully Comprehensive Approach: Limiting Net GHGs in all sectors

Broadening beyond the energy sector to a full net GHG emissions approach, including tree planting and agricultural efforts, can reduce costs further.

Continuing the above analysis, DOE found that applying the GWP tax and in addition allowing a refund for reforestation activities that sequester CO2 would lower the total cost of **reducing US emissions by 20% from 1990 levels by 2010 to about $6-10 billion in 2010 -- over 90% less than the CO2-only, energy-only policy.** Bradley et al., DOE at 8.12. Again, these figures should be taken only to illustrate the likely range of cost savings, since they depend in part upon the IPCC's 1990 GWP figures, which are being recalculated.

An instructive illustration of the cost advantages of a comprehensive approach is provided for India by the World Bank (World Development Report, forthcoming 1992, Box 8.6). **Whereas about 60% of the US GHG emissions portfiolio is in CO2 emissions, for India 60% is in CH4 emissions.** The World Bank analysis assumes that in India the marginal cost of cutting CH4 emissions is higher than is the marginal cost of cutting CO2 emissions, on the theory that Indian CH4 emissions can only be cut by restricting rice and dairy farming. The Bank finds that if India had to cut CO2 emissions by 20% and separately cut CH4 emissions by the same 20% amount -- as well it might if there were separate CO2 and CH4 protocols to a climate convention -- the cost would be over 6 times higher than if India had the flexibility to limit net GHG emissions through its least-cost mix of policies under a comprehensive approach.

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C. Comprehensive marginal cost analyses

Dudek & LeBlanc (Environmental Defense Fund, 1990) find that tree planting is one of the low cost options to limit net emissions: tree planting in the Conservation Reserve Program (CRP) would cost on the order of $3.48-$5.49 per ton of CO2 removed, compared to $5.73 for energy conservation and $4.48 for fuel switching. A similar estimate for tree planting comes from Moulton & Richards (USFS 199), who put the cost per ton of CO2 avoided by tree planting in the US at about $5. Dudek & LeBlanc (1992) report that certain coalbed CH4 recovery techniques have a marginal cost near or below $5 per ton of CO2-equivalent avoided (using GWP=21).

Nordhaus (1990) estimates the marginal cost of global emissions avoidance, taking a comprehensive approach encompassing CO2, CH4, CFCs, and tree planting. He finds that a 10% reduction from 1990 levels can be achieved at a marginal cost of just under $2/ton carbon; this reduction is entirely the phaseout of CFCs. To cut an additional 15%, for a 25% total reduction, would have a marginal cost of $11/ton; most of this reduction is still CFC phaseout, with some of the other sources and sinks beginning to be addressed. After the 25% reduction level costs rise rapidly. Since CFCs were thought in 1990 to represent about 25% of net forcing additions, excluding CFCs on the basis of the new scientific reports in 1991 may mean that we are currently sitting at the point of rapidly increasing marginal costs (the "elbow" in the marginal cost curve).

IV. Note on rebating the revenues of a greenhouse tax.

The economic models of carbon taxes described above in Section I assume that such taxes are revenue-neutral: typically the carbon tax is rebated to individuals on a lump-sum basis. For example, in GREEN the revenues of the carbon tax are offset by reductions in the marginal income tax. EMF used a similar assumption. These models nevertheless show a positive economic cost to restricting emissions.

Some new studies assert that charging a carbon tax and rebating or "recycling" the revenues in special ways different from a lump-sum rebate, such as by reducing taxes on capital or corporate income, could help spur economic growth. Some have gone so far as to assert that rebating carbon taxes to business would reduce the burden on the US economy of a CO2-stabilizing tax to zero or negative costs.

This assertion is controversial. First, economists disagree over how best to rebate the tax, i.e. whether growth is best spurred by a cut in corporate income taxes, an increase in the investment tax credit, or other means. EMF comparisons and EPA

analysis indicate that reducing corporate income taxes or enlarging the investment tax credit would provide a greater spur to economic growth, but which of these two is best is not clear. Reducing the federal deficit or personal income taxes, by contrast, would spur consumption instead of investment, and thereby offset less of the economic costs of a carbon tax (or even exacerbate those costs by inducing inflation to which the Federal Reserve Bank responds by restricting economic growth). (See EMF 12, "Exec. Summary," draft 2/12/92, p. vi.)

Second, and more fundamentally, the key to enhanced growth in these studies is the reduction in the tax burden on labor or capital, not the carbon tax itself. If reducing tax burdens on labor or capital is desirable, and aggregate revenues need to be maintained, other ways of raising the revenue might be more successful and economically efficient than a carbon tax.

V. Engineering studies.

A number of studies have examined not the economic impacts of restraining emissions, but the feasibility of introducing new technologies that together would cut emissions. These "engineering" studies include the Office of Technology Assessment, Changing by Degrees (1991); part of the National Academy of Sciences, Policy Implications of Greenhouse Warming (1991); and the recent study, America's Energy Choices (1991), by NGO groups including the Alliance to Save Energy and the Union of Concerned Scientists.

These studies typically show that large emissions reductions can be obtained at low cost or net savings. This finding is based on assumptions of extensive market failures that can be rectified through better information, commands to employ specific technologies, or other regulation. Yet these studies typically fail to assess the realistic rate of penetration of new technologies into actual usage by real consumers and firms. They also ignore the transition costs of replacing existing technology, adapting existing systems, and so forth. And they typically put no value on consumer preferences or behavior.

Meanwhile, the economic models described above typically do include low-cost and negative-cost technologies in their baselines, and yet they still find positiove costs to imposing emissions limits. (See EMF 12, "Executive Summary" draft 2/12/92, p. ii.)

These studies can be instructive, but they probably trace the lower bound of potential costs to reduce emissions. Moreover, if such low-cost emissions avoidabce options are available, why must society resort to draconian top-down policies to restrict

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emissions? No policy, or just a slight nudge, would presumably be successful.

OTA's study reported that without policy action US CO2 emissions would rise 50% over 1987 levels by 2015. Under a "moderate" scenario of a set of individually identified technology options, US CO2 emissions could be held to 15% above 1987 levels in 2015. A "tough" set of technology options would hold energy use emissions to 29% below 1987 levels in 2015, with another 7% reduction available from forestry measures. OTA says the "moderate" scenario could be achieved at a "net savings" because savings in fuel costs would be larger than capital and operating costs. The "tough" scenario is estimated to cost between a savings of $20 billion and a cost of $150 billion per year, or between 0.2% saved to 1.8% lost from baseline GNP in 2015. (Changing by Degrees (Feb. 1991), "Summary" pp. 9-12.)

OTA's cost estimates are highly dependent on assumed fuel prices; OTA assumes oil will cost $50 per barrel in 2015. If oil actually costs $45 per barrel at that time, the estimated cost would rise $15 billion (wiping out the potential "savings" in the "moderate" scenario). Id. p. 12.

OTA also reported runs using EPA and EPRI models; holding CO2 emissions 10-15% below current levels would lower GNP about 1.0-1.3% by 2015 in the EPA model, while holding emissions 20% below current levels would reduce GNP by 3% by 2015 in the EPRI model. Id. pp. 11-12.

The NAS study also assessed a set of individually identified technology options. Depending on a range of costs and penetration rates, NAS reported that the US could achieve "a substantial reduction in greenhouse gas emissions at low cost, or perhaps even a small net savings." (Policy Implications of Greenhouse Warming (1991), p. 62.) In a chart (Fig. 6.4), NAS compared the technology costing method to economic modeling studies of cost and noted that the latter showed no "savings" but still low cost for early reductions. NAS concluded that at a cost of $10-$20 per ton of CO2-equivalent emissions, the US could reduce emissions by 10% from current levels; it suggested an upper bound of a 40% reduction. Id. p. 63.

The NAS study also concluded, however, that adapting to any climate change could be less costly than severe emissions limits to prevent potential climate change.

America's Energy Choices (1991) reported that significant energy savings could be achieved at a net savings. It reported little detail underlying its cost estimates, making analysis difficult.

DOE analysis indicates that the AEC prediction depends on the assumption of a more rapid sectoral shift in the US economy away from manufacturing and toward services than is assumed by the NES. AEC also assumes rapid pentration of renewables into electricity supply, amounting to 30-50% of supply by 2000 to 70-90% within several decades. AEC predicts a drop in primary energy consumption of 55-57 quads from baseline forecast by 2030; DOE reports that if it had used similar assumptions in its NES analyses, its energy savings projection would have been 46 quads, only 9-11 quads lower than AEC.

AEC also omits from its projections the "rebound" in consumption that occurs when more energy-efficient technology lowers the marginal cost of using the technology and consumers consequently use the technology more. Hence AEC's energy savings projections are somewhat overstated. Further, AEC assumes a CAFE standard of 75 mpg and a $0.50/gallon gasoline tax.

AEC's "cost savings" claim depends on the use of a 3% annual discount rate, which is far below actual discount rates employed by real businesses and consumers; the use of the low discount rate makes far-off fuel price savings seem more valuable. AEC also states that $290 billion per year in new energy and environmental taxes would be need to stabilize C02 emissions; this tax would undoubtedly impose costs on the US economy, but those costs are not identified in the report (perhaps they are embedded in an unexplained cost figure).

<u>Action Agenda policy measures: "Green Lights."</u> Several of the measures identified in the US Action Agenda process are also modeled using the engineering/technology approach. These include the "Green" programs. Their theory is that by adding information, EPA will catapult marketplace adoption of profitable technologies that are currently unused only because of lack of information. The predictions indicate adoption at a net cost savings through 2000. The net cost savings are predicted to continue to grow after 2000, so that the market penetration and energy savings achieved continue growing over time.

The essential debate between DOE and EPA is over the extent of market penetration of these technologies. And even if EPA is correct that the barrier to profitable adoption is lack of information, one must ask why no private entrepreneur has arisen to disseminate this information as EPA is doing.

Assuming EPA is correct about the adoption of Green programs, US emissions might be limited to 1990 levels at low cost. If so, a legislated cap on emissions (e.g. the Waxman bill) would not be a binding constraint and thus would not impose additional cost or additional emissions limitations. If EPA turned out to be incorrect, a legislated limit could turn out to be costly while

constraining emissions.

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VI. Illustrating the uses of cost figures

A. Comparing benefits and costs to the US.

The benefits of limiting GHG emissions are extremely hard to estimate. Making numerous assumptions, Nordhaus (1991) estimates the damage to the US of a 3o C rise in temperature associated with a doubling of CO2-equivalent concentrations at about 0.26% of net national income. Cline (1991) argues that as temperature rises further costs may increase significantly, especially if there are important discontinuities such as changes in deep ocean circulation. Neither the Nordhaus nor Cline estimates of damage take into account the new finding by Karl (1991) that empirically all of the 0.3oC average surface warming observed over the last 50 years has been an increase in minimum (nighttime and wintertime) rather than maximum temperature, suggesting that warming may reduce not increase climate stresses.

These damage estimates can be compared to the cost estimates of emissions avoidance. According to the OECD model comparison, stabilizing US CO2 emissions at 1990 levels after 2000 would cost the US economy 0.1-0.6% of GDP from baseline forecasted GDP in 2000; according to the DRI model, the costs could be more like 1-2%. Costs rise as stabilization is maintained, to 0.3-1.5% of GDP by 2020, and 0.4-2.1% of GDP by 2050. For this illustration, assume an estimate of about 1.0% of GDP.

Stabilizing world emissions at 1990 levels in 2000 will not stabilize concentrations at that level, nor would stabilizing concentrations stop the committed rise in temperature. Stabilizing world emissions at 1990 levels by 2000 would still let CO2 concentrations rise to 500 ppm. by 2100 (OECD, "Evidence from Six Global Models," fn. 8). Stabilizing OECD emissions at 1990 levels by 2000 would reduce global emissions by only about 10% below baseline growth -- not stabilizing global emissions (OECD, "Main Issues" par. 15; CEA/DOE (1990) table III.2). Hence the policy would have only limited effectiveness at slowing temperature rise and would forestall some, but not all and maybe not even a tenth, of the 0.26% damage to the US due to the 3oC rise.

In sum, according to these estimates (which do not account for possible discontinuous damages of climate change), in return for foregoing around 1% of US welfare, a small fraction of the 0.26% damage would be prevented. Calculations for world cost and world benefit could of course be different.

On similar lines, Nordhaus (Sept. 1991) compared several policy hypotheses for world emissions control: no control; "optimal" control in which the world invests to limit net emissions up to the point where the investment is equal to the expected damage from allowing emissions; and stopping temperature change at

1.5 degrees C over 1850 temperature. He assumes policy is pursued efficiently, not uniformly across countries with varying marginal costs. He finds:

% Change in NPV of Consumption	
No control	0.000
"Optimal" control	+0.039
1.5oC limit	-4.657

B. Comparing stabilizing OECD CO2 emissions to stabilizing forest loss.

As indicated above, stabilizing OECD emissions at 1990 levels after 2000 would reduce global CO2 emissions by about 10% from baseline in 2025 (unadjusted downward for "leakage" of carbon emitting-activities to other countries), and cost about 1% of GDP. In the US that would be about $50-100 billion per year (as the US economy grows from $5 trillion in 1992 to $10 trillion in 2025). The total cost to the OECD would be about twice that amount. To be cautious, say a few billion per year in the early 1990s, growing to $25 billion per year by in the decade 2000-2010, to $100 billion per year in 2010-2025. That would sum to an (undiscounted) total of around $2 trillion over the period (and continue growing thereafter).

Deforestation is estimated to contribute about 13% of cumulative global CO2 emissions over 1990-2025. (IPCC "1992 Supplement," Table 2, IS92a scenario.) Stabilizing deforestation now without further forest losses is estimated to cost $52 billion over the ten years 1990-2000, starting at $1 billion per year in 1990 and rising to $8 billion per year for 1997-2000. If, as roughly calculated above, (undiscounted) GDP losses to stabilize OECD CO2 emissions over 1990-2025 amount to somewhere near $2 trillion, this $52 billion is less than 3% of the (undiscounted) cost to stabilize OECD CO2 emissions, for roughly the same impact (or greater) on global CO2 emissions.

In addition, stabilizing forest loss would reap great rewards in terms of biodiversity conservation and other benefits. At the same time, the forest protection investment might be visible earlier than the large CO2 reduction costs, and would be on-budget rather than an effect felt through generalized losses to GDP.